

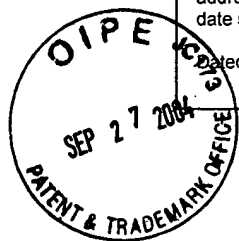
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Dated: 9/24/04

Signature: David T. Yapp

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Docket No.: 535352000500
(PATENT)



IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:

Reamon et al.

Application No.: 09/705,134

Group Art Unit: 2817

Filed: November 2, 2000

Examiner: B. Lee

For: ON-CHIP MULTILAYER METAL
SHIELDED TRANSMISSION LINE

DECLARATION OF PRIOR INVENTION

PURSUANT TO 37 C.F.R. 1.131

Commissioner for Patents
Alexandria, Virginia 22313-1450

Dear Sir:

We the undersigned, , declare as follows:

1. We are the inventors of the above-referenced patent application, and are familiar with its contents.

2. Prior to at least December 30, 1998, we had formed a complete and operative idea of a point of interest spatial search method and system. At our direction, Leonard A. Alkov (Reg. No. 30,021) of Raytheon Company prepared a patent application disclosing this invention, the present application was filed in the United States Patent and Trademark Office on November 2, 2000. The following paragraphs summarize the documents attached to this declaration, which are submitted as evidence of these statements. All of the attached documents were prepared in the U.S.

3. *Exhibit A* is a photocopy of laboratory notes dated between December 6, 1998 to December 9, 1998, by one of the inventors detailing various aspects of an on-chip multilayer metal shielded transmission line. As shown in the notes, calculations and drawings were generated for practicing a shielded monolithic transmission line having particular dimensions and spacings.

4. *Exhibit B* is a photocopy of an inventor disclosure that was submitted by the named inventors to the Raytheon company, detailing certain final aspects of the invention. The inventor disclosure was reviewed, revised, and placed into final form for filing with the USPTO.

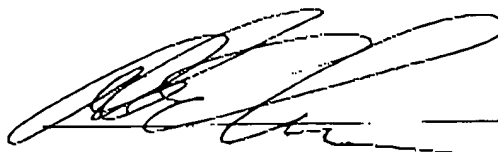
5. We have reviewed U.S. Patent No. 6,133,621, by Gaibotti et al., provided by the U.S. Patent Office accompanying the Office Action mailed on March 24, 2004. Gaibotti was filed in the U.S. on December 30, 1998, and issued on October 17, 2000. Contained therein is an integrated shielded connection for use inside an integrated circuit.

6. The subject matter we desire to claim does not correspond to a lost count in an interference and is not otherwise barred to the applicants. We do not believe that the invention was in public use or on sale in this country, patented or described in a printed publication in this or any foreign country more than one year prior to the filing of this application. We never abandoned the invention before the filing date of this application.

7. We hereby declare that all statements made herein of our own knowledge are true and that all statements made on information and belief are believed to be true. We declare that all these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

9/22/04

Date



Alan E. Reamon

09/22/04

Date



Lloyd F. Linder

9/22/04

Date



Erick M. Hirata

Date

Nick Elmi

Heer knows someone but has no experience + he probably doesn't want to come to Raytheon
Heer said he left because he got no respect from anyone

based on
Mike's
calculations

Lat. 12/05/98 (0.8 μm) (X MCM)

$$L = .266 \text{ pH}/\mu\text{m}$$

$$C = .163 \text{ fF}/\mu\text{m}$$

$$\text{want } \frac{1}{2\pi} = f_0 = 150 \text{ GHz} = \frac{1}{2\pi LC}$$

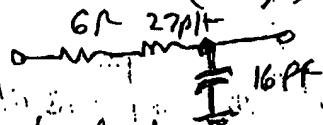
What is the current handling capability for the metals?

$$\sqrt{LC} = \frac{1}{2\pi(150 \text{ GHz})} \Rightarrow LC = 1.125 \times 10^{-24} \text{ s}^2$$

for 100 μm , $L = 26.6 \text{ pH}$ $C = 16.3 \text{ fF}$

$$45 \text{ m}\Omega/\square \left(\frac{100 \mu\text{m}}{0.8 \mu\text{m}} \right) \left(\frac{45 \text{ m}\Omega}{\square} \right) = 5.6 \Omega \quad \text{for } 3 \mu\text{ wide line}$$

$$R_s = 1.5 \Omega$$



don't think we can use 0.8 μm anyways due to current


$$\text{TIA cell} \sim 1.3 \times 1.6 \text{ mil} = 2.1 \text{ mil}^2$$

Sun. 12/06/98

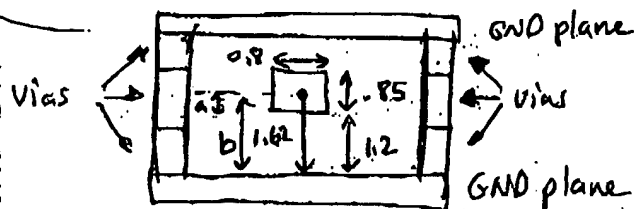
Don't see any caps on TIA layout

questions for TIA:

- 1) What is temp room or cryo?
- 2) do they have cryo models? What does β do?
- 3) what's their resistor width? current density?

the conductor dimensions are 0.8×0.8 
a circle of diameter $0.8 \mu\text{m}$ is close to that.

Nick assumed that the stripline structure was basically a coax (that's why he said that we should put a wall around the conductor).



$$a = 0.42 \mu\text{m}$$

$$b = 1.62 \mu\text{m}$$

(*)

All calculations assume $0.8 \mu\text{m}$ wide line

distributed inductance \Rightarrow

$$\mu_m = \mu_r \mu_0 \quad \mu_r = 1 \quad \text{glass - assumed}$$

$$L = \frac{\mu_m}{2\pi} \ln\left(\frac{b}{a}\right) \quad b, a \text{ defined above}$$

$$L = \frac{\mu_0}{2\pi} \ln\left(\frac{b}{a}\right) \quad \mu_0 = 4\pi \times 10^{-7} \frac{\text{Henries}}{\text{meter}}$$

$$= \left(4\pi \times 10^{-7} \frac{\text{H}}{\text{m}}\right) \left(\frac{1}{2\pi}\right) \left(\frac{1\text{m}}{10^6 \mu\text{m}}\right) \ln\left(\frac{1.62}{.42}\right)$$

$$= \left(2 \times 10^{-13} \frac{\text{H}}{\mu\text{m}}\right) (1.34) = 2.68 \times 10^{-13} \frac{\text{H}}{\mu\text{m}} = \boxed{268 \frac{\text{fH}}{\mu\text{m}}}$$

now this equation assumes:

- 1) circular conductors for all planes
- 2) $\mu_r = 1$ \rightarrow assumption is the material in the interconductor space of the coax line has the magnetic properties of free space.

characteristic impedance $Z_0 = \sqrt{\frac{\mu_m}{(2\pi)^2 \epsilon'}} \ln\left(\frac{b}{a}\right) = \frac{138 \sqrt{\mu_r}}{\sqrt{\epsilon_r}} \log_{10}\left(\frac{b}{a}\right)$

$$= \boxed{40.96 \text{ ohms}}$$

Nick verified this from a chart for a symmetric stripline w/ finite conductor thickness. So these approximations seem to be valid.

distributed capacitance $C = \frac{2\pi \epsilon_r \epsilon_0}{\ln \frac{b}{a}} \text{ F/m}$

$$\epsilon_r = 3.9 \quad \epsilon_0 = 8.85 \times 10^{-12} \frac{\text{F}}{\text{m}}$$

$$C = \frac{2\pi (3.9) (8.85 \times 10^{-12})}{\ln\left(\frac{1.62}{.42}\right)} \text{ F/m} = \boxed{.161 \frac{\text{fF}}{\mu\text{m}}}$$

therefore, his assumption of a circular conductor was valid to approximate the rectangular conductor.

distributed conductance

$$G = WC \tan \delta \quad \omega = 2\pi \times 1.5 \text{ GHz}$$

glass is assumed, so loss tangent = $\tan \delta = .006$

$$\text{@ } 1.5 \text{ GHz, } G = (2\pi)(1.5 \times 10^9)(.006)(.161 \text{ fF}/\mu\text{m}) = 9.1 \text{ nS}/\mu\text{m}$$

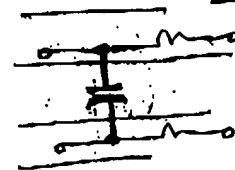
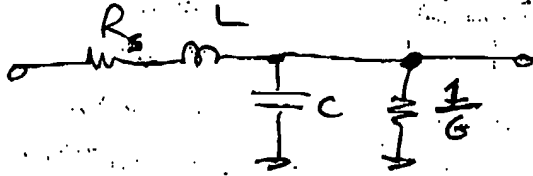
$$\text{@ } 20 \text{ GHz, } G = 12.1 \text{ nS}/\mu\text{m}$$

unit
resonant
frequency

$$f_{\text{unit length}} = \frac{1}{2\pi \sqrt{LC}} = \frac{1}{2\pi \sqrt{(0.161 \text{ fF}/\mu\text{m})(268 \text{ fH}/\mu\text{m})}}$$

$$= [24 (\text{THz}/\mu\text{m}) \text{ unit length}]$$

$$f_{\text{res}} = [f_{\text{unit length}}] \cdot \left(\frac{1}{\sqrt{L}} \right) \quad L \text{ is in } \mu\text{m}$$



do sidewall
cap for
coupling,
don't know
about material
inductance.

$$R_s = \frac{1}{\sigma \delta_s} \frac{1}{2\pi b} \left(1 + \frac{b}{a} \right) \quad \Omega/\text{meter}^2$$

$$\sigma = \text{conductivity of aluminum} = 3.54 \times 10^7 \frac{\text{S}}{\text{meter}}$$

$$\delta_s = \sqrt{\frac{2}{\omega \mu_0 \sigma}}$$

ω = frequency of operation

as $\omega \uparrow$ so used 20 GHz (less damping)

$$\delta_s = \sqrt{\frac{2}{(2 \times 10^9 \text{ s}^{-1})(4\pi \times 10^{-7} \text{ H/m})(3.54 \times 10^7 \text{ S/m})}}$$

$$= 1.9 \times 10^{-6} \text{ m}$$

distributed
resistance

$$R_s = \frac{1}{\sigma} \cdot \frac{\sqrt{2\pi f \mu_0 \sigma}}{\sqrt{2}} \cdot \frac{1}{2\pi b} \left(\frac{a+b}{a} \right)$$

$$= \frac{\sqrt{2\pi f \mu_0 \sigma}}{\sqrt{2} \sigma} \cdot \frac{1}{2\pi b} \left(\frac{a+b}{a} \right) = \sqrt{\frac{f \mu_0}{4\pi \sigma}} \left(\frac{a+b}{ab} \right)$$

$$= \sqrt{\frac{(2 \times 10^9)(4\pi \times 10^{-7} \text{ H/m})}{4\pi (3.54 \times 10^7 \text{ S/m})}} \left(\frac{.42 + 1.6}{(.42)(1.62 \mu\text{m})} \right)$$

$$= (2.38 \times 10^{-3} \frac{\Omega}{\text{m}}) \left(\frac{1 \text{ m}}{10^6 \mu\text{m}} \right) \left(\frac{2.97}{\mu\text{m}} \right) = 7.1 \frac{\Omega}{\mu\text{m}^2} \quad * (W \times L)$$



p4/n

95 Ω/\square M3. Does this agree?

for 100 μm long, 3 μm wide

$$\delta s = 1.70 \mu m$$

$$\tan \delta = .006$$

$$\lambda_0 = 9 \text{ f}$$

$$f = 2 \times 10^7 \text{ s}^{-1} \quad \lambda_0 = .15 \text{ m}$$

insertion loss

$$\alpha = \alpha_{\text{conductor}} + \alpha_{\text{dielectric}}$$

$$\alpha_{\text{dielectric}} = 27.3 \frac{\sqrt{\epsilon_r}}{\lambda_0} \tan \delta$$

$$\alpha_{\text{dielectric}} = \frac{27.3 (3.9) (.006)}{.15 \text{ m} (10^6 \mu m)} \text{ m}^{-1}$$

$$= 2.15 \times 10^{-6} \text{ dB}/\mu m$$

$$\frac{b}{a} = \frac{1.62}{.42}$$

$$= 3.9$$

units are
dB/m
according
to Nick

$$\alpha_{\text{conductor}} = \frac{23.6 \delta_s \sqrt{\epsilon_r} (1 + b/a)}{\lambda_0 b [\ln(b/a)]}$$

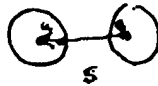
$$\alpha_{\text{conductor}} = \frac{(23.6) (1.70 \mu m) (3.9) (1 + 3.9) (1 \text{ m})}{(.15 \text{ m}) (1.62 \mu m) [\ln(3.9) (10^6 \mu m)]}$$

$$= 0.000755 \text{ dB}/\mu m$$

$$= 7.55 \text{ dB}/\text{cm}$$

this
analysis
may not
be valid.

parallel conductor



$$\frac{s}{2a} = 1$$

$$C = \frac{\pi \epsilon_0 \epsilon_r}{\ln \left[\frac{s}{2a} + \sqrt{\left(\frac{s}{2a} \right)^2 - 1} \right]} \text{ F/m}$$

$$= \frac{(\pi) (3.9) 8.85 \times 10^{-12} \text{ F/m}}{\ln \left[\frac{3.8}{3.0} + \sqrt{\left(\frac{3.8}{3.0} \right)^2 - 1} \right]}$$

$$= .151 \text{ pF}/\mu m$$

assume same approxi-
mations as before

for

$$a = 1.5 \mu m$$

$$s = 3.8 \mu m$$

$$= 151 \times 10^{-12} \text{ F/m}$$

$$L = \frac{\mu m}{\pi} \cosh^{-1} \frac{s}{2a} = \frac{\mu m}{\pi} \ln \left[\frac{s}{2a} + \sqrt{\left(\frac{s}{2a} \right)^2 - 1} \right] \frac{\text{H}}{\text{m}}$$

$$= \left(4 \times 10^{-7} \frac{\text{H}}{\text{m}} \right) \left(\frac{1 \text{ m}}{10^6 \mu m} \right) \left(\frac{1}{\pi} \right) \ln \left[\frac{3.8}{3.0} + \sqrt{\left(\frac{3.8}{3.0} \right)^2 - 1} \right]$$

$$= 91 \text{ fH}/\mu m$$

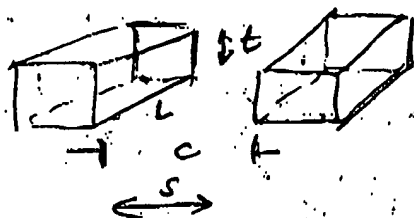
$$\epsilon_r' = \epsilon_r \epsilon_0 / \epsilon_0$$

$$Z_0 = \frac{120}{\sqrt{\epsilon_r}} \ln \left[\frac{s}{2a} + \sqrt{\left(\frac{s}{2a} \right)^2 - 1} \right] = \frac{120}{\sqrt{3.9}} \ln \left[\frac{3.8}{3.0} + \sqrt{\left(\frac{3.8}{3.0} \right)^2 - 1} \right]$$

$$Z_0 = 43 \Omega$$

Nick - coupling has to ~~be~~ measured.

Nick says if that the conductors are spaced far enough apart, there is no mutual inductance only mutual capacitance



$$\frac{\epsilon_0 A}{d} = C \text{ coupling between conductors}$$

$$A = tL \quad C = \left(\frac{\epsilon_0 tL}{s} \right)$$

list of programs clin working on to Bob Ferreira. sent him email.

1) Ultracomm

2) ACS

Expense APD

3) Bidding - ROIC → due Dec. 15th

4) RF Switch

5) ADRT → design review this Thursday. I need to do viewgraphs

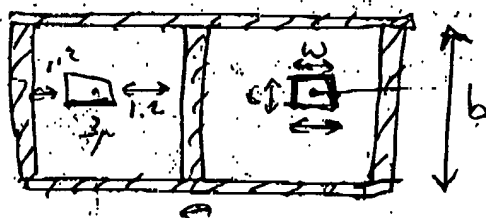
6) INX Risk Reduction

7) Support ROAD, SW ABs,

New business opportunities

8) SiGe process characterization

best way to go →



Nick's reference for above for coupled conductors

$$Z_0 \sqrt{\epsilon_r} = \frac{94}{X(w/b) + \frac{4}{\pi} F(X)}$$

$$X = 1 - t/b$$

$$F(X) = \frac{(X+1)^{X+1}}{(X-1)^{X-1}}$$

$$t = .85$$

$$w = 3$$

$$b = 3.2$$

$$X = 1 - \frac{.85}{3} = .72$$

$$F(X) = \frac{(1.72)^{1.72}}{(.72-1)^{.72-1}}$$

this doesn't work out unless abs. value $F(X) = 3.6$

$$Z_0 \sqrt{\epsilon_r} = \frac{94}{\frac{1}{\pi} (3.6) + (.72) \left(\frac{2}{3.2} \right)}$$

$$Z_0 = 26.1 \Omega$$

see 3 pages over

$$Z_0 = \sqrt{\frac{L}{C}}$$

w = width of conductor

t = thickness of the conductor

b = distance bet. GND conductors



Cliff: has to drive large cap @ the output @ the mixer. Remove it, & see if it's a problem. Pres is still a problem but uses same one as the ^{1st} (wh?) from one of Nick's books.

for micro layer
dielectric
 $\frac{1}{b} = \frac{1.85}{3.1}$
 $= .265$

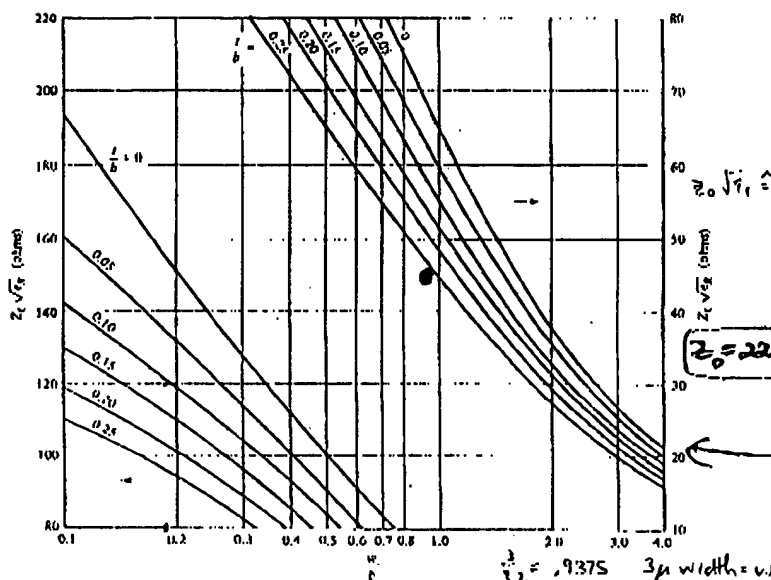
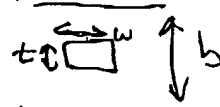


Figure 5-8 Characteristic impedance data for stripline. A nonmagnetic dielectric is assumed ($\mu_r = 1.0$). Also $a \gg w$ and $a \gg 2b$. (From S. Cohn, Ref. 5 [4]; © 1955 IRE; now IEEE, with permission.)

$$Z_0 = \frac{\sqrt{\mu_r \epsilon_r}}{3 \times 10^8 C'} \text{ ohms}$$

$Z_0 \sqrt{\epsilon_r} = 45 \Omega$ C per unit length of a stripline

$Z_0 = 220 \Omega$ → this is close to the 260 Ω calculated for general case of $t/b, w/b$



Stripline

DCD gave me this. R.N.S EXCEL spreadsheet for Z_0 calculations.

see what Robert's program spits out

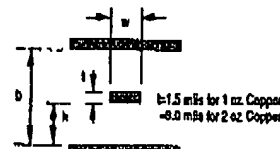
| | | | |
|-----------------------|------|------|----------------------|
| er (board dielectric) | 3.90 | 4.70 | 4.79 |
| h (dielectric height) | 1.2 | 1.2 | 1.2 mils |
| w (line width) | 3 | 3 | 3 mils |
| t (Copper thickness) | 0.85 | 0.85 | 0.85 mils 1/2 oz. Cu |

OTOROLA MECL SYSTEM DESIGN

| | | | |
|--------------------------|-----------|-----------|-----------|
| $w/(b-t) < 0.35$ | 8.57 | 8.57 | 8.57 |
| $t/b < 0.25$ | 0.71 | 0.71 | 0.71 |
| Motorola Equation Valid? | Maybe Not | Maybe Not | Maybe Not |
| z_0 (Motorola MECL) | 19.51 | 17.77 | 17.59 |

S.B. Cohn, J.F. White

| | |
|---|-------|
| $w/(2*b) < 0.35$ Narrow, ≥ 0.35 Wide | 1.25 |
| White, Cohn Narrow or Wide? | Wide |
| z_0 (White, Cohn) | 23.74 |

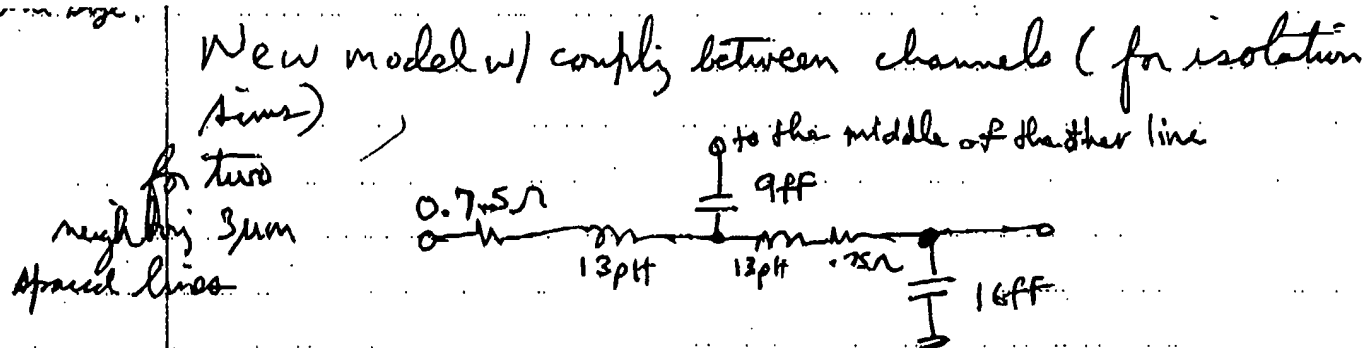


Stripline For PCB Calculation

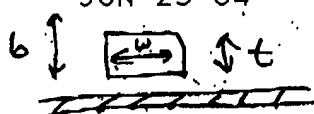
| | | | |
|---|---|--------|----------------------|
| er (board dielectric) | 4.47 | 4.70 | 4.79 |
| h (dielectric height) | 31 | 31 | 31 mils |
| w (line width) | 9 | 9 | 9 mils |
| t (Copper thickness) | 0.75 | 0.75 | 0.75 mils 1/2 oz. Cu |
| OTOROLA MECL SYSTEM DESIGN | | | |
| $w/(b-t) < 0.35$ | 0.30 | 0.30 | 0.30 |
| $t/b < 0.25$ | 0.02 | 0.02 | 0.02 |
| Motorola Equation Valid? | OK | OK | OK |
| z_0 (Motorola MECL) | 75.89 | 74.25 | 74.21 |
| S.B. Cohn, J.F. White | | | |
| $w/(2*b) < 0.35$ Narrow, ≥ 0.35 Wide | 0.15 | 0.15 | 0.15 |
| White, Cohn Narrow or Wide? | Narrow | Narrow | Narrow |
| z_0 (White, Cohn) | 77.47 | 75.61 | 76.77 |
| OTHER COMBINATIONS OF (er, w, h, t) | (21.8), (24.7), (27.8), (31.8), (34.10) | | |

Stripline For PCB Calculation

| | | | |
|---|------------------------------------|-----------|----------------------|
| er (board dielectric) | 4.47 | 4.70 | 4.79 |
| h (dielectric height) | 31 | 31 | 31 mils |
| w (line width) | 25 | 25 | 25 mils |
| t (Copper thickness) | 0.75 | 0.75 | 0.75 mils 1/2 oz. Cu |
| OTOROLA MECL SYSTEM DESIGN | | | |
| $w/(b-t) < 0.35$ | 0.83 | 0.83 | 0.83 |
| $t/b < 0.25$ | 0.02 | 0.02 | 0.02 |
| Motorola Equation Valid? | Maybe Not | Maybe Not | Maybe Not |
| z_0 (Motorola MECL) | 49.89 | 48.40 | 47.89 |
| S.B. Cohn, J.F. White | | | |
| $w/(2*b) < 0.35$ Narrow, ≥ 0.35 Wide | 0.40 | 0.40 | 0.40 |
| White, Cohn Narrow or Wide? | Wide | Wide | Wide |
| z_0 (White, Cohn) | 51.23 | 50.02 | 49.84 |
| OTHER COMBINATIONS OF (er, w, h, t) | (13,10), (19,15), (25,20), (31,26) | | |



for a stripline of general width



$$C_f' = \frac{0.885\epsilon}{\pi} \left[\frac{2}{1-t/b} \ln \left\{ 1 + \frac{1}{1-t/b} \right\} - \left(\frac{1}{1-t/b} - 1 \right) \ln \left(\frac{1}{(1-t/b)^2} \right) \right]$$

pF/cm

$$t/b = .85/3.2 = .265 \quad \frac{1}{1-t/b} = 1.36$$

$$C_f' = \frac{0.885\epsilon}{\pi} \left[(2.72)(.858) - (.36)(-.162) \right] \text{ pF/cm}$$

$$= 67.37 \times 10^{-3} \text{ pF/cm} = (262.7 \text{ pF/cm}) \left(\frac{1 \text{ cm}}{10^4 \mu\text{m}} \right) = 26.27 \times 10^{-6} \text{ pF}$$

$$= 26.2 \text{ pF}/\mu\text{m} = .0262 \text{ fF}/\mu\text{m}$$

seems small, but I guess it's ok. It's only fringe

$$Z_{0FE} = \frac{94.15}{\left(\frac{w/b}{1-t/b} \right) + \frac{C_f'}{0.885\epsilon}} = \frac{94.15}{1.275 + .761} = 46.2$$

C_f is fringe capacitance, not C

$$Z_0 = 23.3 \Omega \text{ w } 3 \mu\text{m} \text{ from three different approaches, get } Z_0 = 35 \Omega \text{ for } w=1.5 \mu\text{m } 23, 22, 26. \text{ Very close. R.N's program says } 24 \Omega$$

$$Z_0 = \sqrt{\frac{L}{C}} = 23.3$$

$$\sqrt{\frac{14.2 \times 10^{-15}}{26.2 \times 10^{-10}}} = 23.2 \Omega$$

for two stripline conductors next to each other:

$$\text{w/ply } .27 + .27 C_0 = 1 - C_0$$

$$1.27 C_0 = .729$$

$$C_0 = .574$$

- 5dB coupling!

strategy: do the single stripline sims first. On Friday create the coupled stripline model

if we want 60dB isolation

$$C_0 = .001 \Rightarrow Z_{00} = 1.001 (\text{norm})$$

$$Z_{00} = 50.05 \Omega \text{ un-normalized}$$

can't do it. Need wall'd conductors. Requirement not exactly true. Z_{00} is for differential signals. We should look @ 2 S/E signals, so even mode.

I think C_0 assumes a 50 Ω system, ~~across~~
 why Z_0 has to be close to 50 Ω to get good
 $C_0 = .001$ isolation. May not be true for our case.

$$Z_{0e} = 1.0010005 \text{ (normalized)}$$

$$= 50.05 \Omega \text{ } \mu\text{m}$$

$$\sqrt{Z_r Z_{0e}} = 98.8 \Omega$$

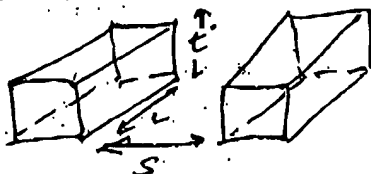
$$Z_{0e} = 27$$

$$.604, 22$$

system \Rightarrow

conclusion: with a 3 μm width = w , Z_{0e} is lower than
 50 Ω , + from the equations, this causes poor coupling in a 50 Ω
 need a well bt. conductors in 50 Ω system, but we're ~~not~~ in a
 50 Ω system, so what does that mean?

coupling cap $C = \epsilon_r \epsilon_0 A/d$

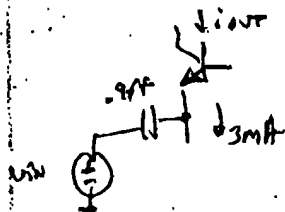


$$C = \epsilon_0 \epsilon_r \frac{L w}{d}$$

$$S = 3 \mu\text{m} \quad L = 100 \mu\text{m} \quad t = .8 \mu\text{m}$$

$$C = (8.85 \times 10^{-12} \text{ F/m}) (3.9) \left(\frac{1 \text{ m}}{10^6 \mu\text{m}} \right) (100 \mu\text{m}) \frac{(0.85 \mu\text{m})}{3 \mu\text{m}}$$

$$= 978 \text{ aF} = .97 \text{ fF}$$



$$\frac{8 \Omega}{8 \Omega + \frac{1}{2 \pi (2 \pi \times 10^8) (.97 \text{ fF})}}$$

$$= \text{coupling} = 98 \times 10^{-6}$$

$$= -80 \text{ dB}$$

Nick said that if the conductors are far enough away, there's
 no mutual inductance. c/s 3 μm far enough?
 Billy will need to sim the coupling of microstrip
 lines on the layout of the IC - that would be better

Tues. 12/08/98

asked Al Keamron to go over sizes on the layout + then
 we'll call Wayne

Tues 12/09/98

asked Kelvin to look @ parasitics on one section only. He's doing

that.

Nicks' calculations for strip line L, C 3um wide

$$v = \frac{c}{\sqrt{\epsilon_r}} = 152 \times 10^6 \text{ m/sec}$$

$$Z_0 = 23\Omega = \sqrt{L/C}$$

$$\text{and } 152 \times 10^6 \frac{\text{m}}{\text{s}} = \frac{1}{\sqrt{L \cdot C}} \quad \text{where } L, C \text{ in } \frac{\text{H}}{\text{m}} \text{ and } \frac{\text{F}}{\text{m}}$$

$$R_g = 9.96 \text{ m}\Omega/\mu\text{m} \quad \Omega/\text{unit length} \quad \frac{W \delta_s \sigma}{\text{length}}$$

$$\frac{\text{sec}}{\text{cm}} \times \mu\text{m} = \frac{\text{sec}}{\text{cm}} = \frac{\Omega}{\mu\text{m}} \text{ ok}$$

$$C = .267 \text{ fF}/\mu\text{m} \times (100 \mu\text{m}) = 26.7 \text{ fF}$$

CLOSE

$$L = .162 \text{ pH}/\mu\text{m} \times (100 \mu\text{m}) = 16.2 \text{ pH}$$

gave to Kelvin, let $R=0$

$$R_s = \left(\frac{W \mu_0 \delta_s}{2} \right)$$

$$\delta_s = \text{skin depth} = \sqrt{\frac{2}{W \mu_0 \sigma}}$$

 σ = conductivity of aluminium

$$\delta_s = \sqrt{\frac{2}{2\pi(2 \times 10^9 \text{ s}^{-1})(4\pi \times 10^{-7} \text{ H/m})(3.54 \times 10^7 \text{ s}^{-1})}}$$

$$\delta_s = 1.89 \times 10^{-6} \text{ meters}$$

$$R_s = 2\pi(2 \times 10^9 \text{ s}^{-1})(4\pi \times 10^{-7} \text{ H/m}) \left(\frac{1.89 \times 10^{-6} \text{ m}}{2} \right) = 14.9 \text{ m}\Omega$$

Nich said that equation doesn't make sense. 2 should be able to use σ + the geometry to get $R_s/\text{length} = \left(\frac{1}{\sigma + W} \right) = \left(\frac{1}{\sigma} \right) \left(\frac{1}{W} \right) = \left(\frac{1}{\sigma} \right) \left(\frac{1}{\text{length}} \right)$

$$\text{Losses } \alpha_d = \frac{\pi \sqrt{\epsilon_r}}{\lambda_0} \text{ from } S = \frac{\pi \sqrt{3.8}}{(3 \times 10^8 \text{ m/s})} (2.0 \times 10^9 \text{ s}^{-1}) (0.06) \left(\frac{1}{\text{length}} \right) = 11.2 \text{ m}\Omega/\mu\text{m}$$

$$\alpha_c = \frac{R_s \epsilon_r Z_0}{120\pi(94.156)} \left[\frac{1}{1 - \frac{W}{b}} + \frac{2W/b}{(1 - \frac{W}{b})^2} + \frac{(1 + \frac{W}{b})}{\pi(1 - \frac{W}{b})^2} \ln\left(\frac{2 - \frac{W}{b}}{\frac{W}{b}}\right) \right]$$

$$\alpha_c = 649 \text{ dB}/\mu\text{m} = 0.000649 \text{ dB}/\mu\text{m} = 6.5 \text{ dB}/\text{cm} = 736 \text{ dB}/\text{cm}$$

Reamon will send Wayne an email + cc: Kent
McLormack



$$\alpha_c = \frac{R_s}{2} \sqrt{\frac{1}{\epsilon_r}}$$

$$\frac{1}{b} = \frac{0.85}{3.2} = .26$$

$$\frac{1}{b} = \frac{0.85}{3.2} = .26$$

Fri. 12/11/98

Stripline analysis continued (redo the $3\mu\text{m}$ analysis for
for $W = 1.5\mu\text{m}$ $1.5\mu\text{m}$ width).

$$Z_0 = 35\Omega$$

$$Z_0 = \sqrt{\frac{L}{C}} \quad v = 152 \times 10^6 \frac{\text{m}}{\text{s}} = \frac{1}{\sqrt{LC}}$$

L, C in $\text{H}/\mu\text{m}, \text{F}/\mu\text{m}$ units

$$(35\Omega)^2 = \frac{L}{C} \quad (152 \times 10^6 \frac{\text{m}}{\text{s}})^2 = \frac{1}{LC}$$

$$(35\Omega)^2 C = L \Rightarrow C^2 = \frac{1}{(35\Omega)^2 (152 \times 10^6 \text{ m/s})^2} = \frac{187.9 \text{ pF}}{\text{m}} = .187 \text{ fF}/\mu\text{m}$$

$$L = 229 \text{ fH}/\mu\text{m} = .23 \text{ pH}/\mu\text{m}$$

$$R_s = 14.9 \text{ m}\Omega \quad (\text{from 14 pgs back}) \quad \delta_s = 1.89 \times 10^{-6} \text{ cm} \quad (14 \text{ pgs back})$$

$$R = 19.96 \text{ m}\Omega/\mu\text{m}$$

$$f_0 = \frac{\omega_0}{2\pi} = \frac{1}{2\pi} \frac{1}{\sqrt{LC}} = 240 \text{ GHz}/\mu\text{m length}$$

$$\alpha_d = 2.15 \times 10^{-6} \text{ dB}/\mu\text{m}$$

$$\alpha_c = \frac{R_s \epsilon_r Z_0}{120 \pi (24.15) b} \left\{ \frac{1}{1 - \frac{1}{6}} + \frac{2 \frac{1}{6}}{(1 - \frac{1}{6})^2} + \frac{(1 + \frac{1}{6})}{\pi (1 - \frac{1}{6})^2} \ln \left[\frac{2 - \frac{1}{6}}{(\frac{1}{6})} \right] \right\} \frac{\text{np}}{\mu\text{m}}$$

4.437
1.35 1.7 .73 1.5

$$= 80.0 \times 10^{-6} \text{ np}/\mu\text{m} = 69.5 \text{ udB}/\mu\text{m}$$

$$= .000695 \text{ dB}/\mu\text{m} = 6.95 \text{ dB/cm}$$

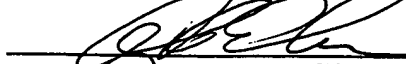
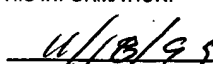
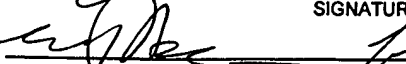
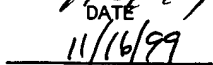
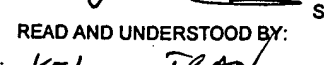

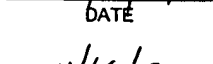
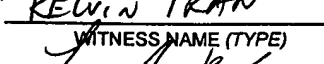
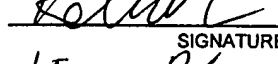
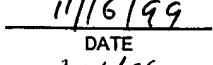
8. SUMMARY OF THE INVENTION

A. GIVE A BRIEF DESCRIPTION OF YOUR INVENTION, PARTICULARLY POINTING OUT WHAT IS BELIEVED TO BE NOVEL (THE 'HEART' OF WHAT IS NEW).

The requirement for on-chip isolation for the multi-channel RF Switch forced the development of true isolated, shielded conductors on-chip, using the multi-layer metal of the SiGe BiCMOS technology. The only process requirement for the realization of the shielded conductor is $N > 3$ metal layers. However, the fine-line geometries of the metal used in the SiGe BiCMOS allowed the thickness and minimum width of the metal conductor to be on the same order, thereby allowing the conductor the ability to have the characteristics of an on-chip coaxial line. Equations were developed to calculate the characteristic impedance of the line, and the inductance and capacitance. This novel structure allows the solution for the Teledesic program to remain monolithic, exceed isolation requirements, and not take up a significant amount of silicon area that would be required to implement the solution using on-chip microstrip or stripline structures. Another unique feature of the concept is to have continuous stacked vias to truly encase the center conductor. This is a key process feature that is a requirement to maintain tight routing while meeting the isolation requirements.

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FO0299 MAY 98

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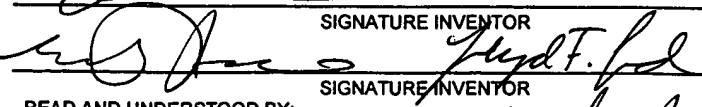
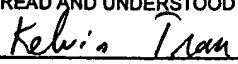
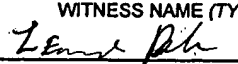
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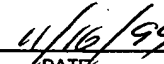
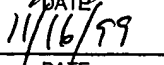
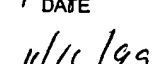
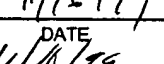
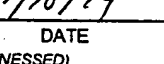
B. EXPLAIN THE PURPOSE AND ADVANTAGES OF YOUR INVENTION. (WHAT WILL THE INVENTION DO BETTER THAN DONE PREVIOUSLY?)

The advantages of this invention is it provides, for the first time, a truly isolated on-chip coaxial conductor. The prior art for the required performance takes up significant silicon in order to meet the isolation requirement, and this causes an impractical die size when the number of inputs and outputs for the RF switch gets large. The unique solution developed here allows for almost perfect isolation on-chip, this solution comes about as a result of multi-layer metal and the ability to have nearly continuous interlayer metal via stacks along the ground shield walls of the conductor. In the limit, conductors can be spaced, at minimum spacing, to a ground plane consisting of all layers of metal with nearly continuous ^{stacked} metal vias between the layers. This will allow large M X N matrix arrays to be implemented monolithically and meet the isolation specification while keeping the die size small. Previously, microstrip or stripline structures had to be used on-chip and distance between conductors was the only way to isolate signals. This is due to the fact that the metal technology could not yield long intermetal via structures, it could not yield stacked interlayer metal via structures and most definitely could not yield large numbers of long, stacked interlayer metal via structures. With the yield of today's metal technology, this concept is implementable and yieldable.

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see attached copy of proposal

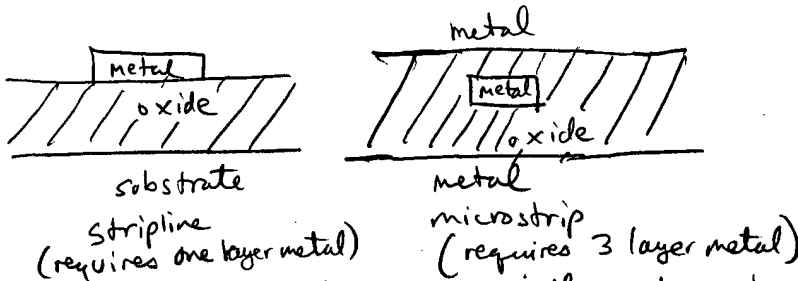
8. SUMMARY OF THE INVENTION (Continued)

C. IDENTIFY THE COMPANY PROGRAM OR PRODUCT LINE TO WHICH THE INVENTION APPLIES, AND THE EXPECTED VALUE TO THE PROGRAM OR PRODUCT LINE. ALSO IDENTIFY POTENTIAL COMMERCIAL APPLICATION OF THIS INVENTION, INCLUDING AUTOMOTIVE APPLICATIONS, IF ANY.

The invention was generated as part of the proof-of-concept phase for the Teledesic program for Motorola. If the Raytheon is chosen as part of the competitive bid process, the production options will mean \$50-\$150M in sales for the company. Also, the Emerging Business Group is seeking outside venture capital to apply the RF Switch concept to the cellular Infrastructure Base station market in the PCS frequency range.

D. IDENTIFY THE PRIOR ART KNOWN TO YOU WHICH IS IMPROVED UPON OR DISPLACED BY YOUR INVENTION, AND STATE IN DETAIL, IF KNOWN, THE DISADVANTAGES OF THE CLOSEST PRIOR ART.

The prior art is the on-chip microstrip and stripline (shown below)



During the Teledesic program, these two structures were used to design the required isolation specifications using the HFSS EM simulator. For either structure, isolation improved only as two neighboring conductors were placed further and further apart. This requires a large amount of silicon area just for routing to guarantee that there is no coupling between channels. Since there are 30 differential inputs and 10 differential outputs on the proof-of-concept IC for Teledesic, this would require a large amount of silicon, based on electromagnetic simulations, in order to guarantee the difficult isolation specification. The solution proposed here provides better isolation performance in a smaller silicon area, with tighter control on the characteristic impedance as a result of the isolation. One of the reasons that previous multi-layer metal (≥ 3 layers) could not implement the shielded coaxial line on-chip was the inability to allow stacked inter-metal layer vias. Inter layer metal vias were not allowed to be stacked previously due to yield limitations. Modern fabrication technologies have overcome this limitation to enable this unique solution.

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9. DETAILED DESCRIPTION



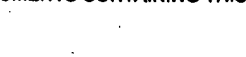





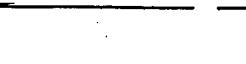
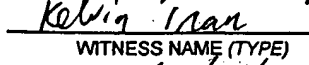
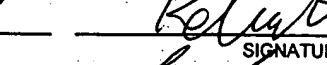
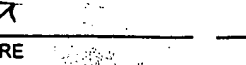
DESCRIBE YOUR INVENTION IN DETAIL, USING NECESSARY ADDITIONAL SHEETS

- A. BE SURE THAT EACH SHEET IS DATED, AND SIGNED BY EACH INVENTOR AND TWO WITNESSES. (F00299 PAGE 6 SHOULD BE USED, IF PRACTICAL).
- B. ATTACH COPIES OF DRAWINGS OR DETAILED REPORTS HELPFUL IN UNDERSTANDING HOW YOUR INVENTION WORKS
- C. IF YOUR INVENTION HAS BEEN TESTED, BRIEFLY SUMMARIZED THE TEST RESULTS WHICH CONFIRM THE FUNCTIONS AND ADVANTAGES LISTED IN 8 B ABOVE.

The basic cross-section of the idea is shown on page 8. For the 5 layer metal process, the center conductor (metal 3) is used. This solution allows the minimum impact from parasitics, but also from a symmetry standpoint allows the coaxial solution. For N layers of metal ($N \geq 3$), the conductor should be layer $(\frac{N+1}{2})$. The fine geometries of modern-day metal processing technology allows the dimensions of the center conductor to approximate a coaxial line, when shielded as shown on page 7. One of the key enablers to meeting the isolation spec is the stacked, stretched multi-layer vias which allow nearly continuous closure of the center conductor. Some of the features of this structure are briefly described on page 8. Page 9 shows a layout of the RF Switch Proof-of-Concept IC which utilizes this concept. As can be seen from the layout plot, the routes are fairly closely spaced on the layout, with the expected measurement result that the circuit meets the isolation requirements. The long routes on the layout are actually differential lines, which are placed with a common ground plane, as shown on page 8, to help with minimization of the chip size. As a result of the structure of the coax line, this can be done without compromising isolation. It can be seen from page 9, layout that there are spots in the layout where the shielded coaxial lines (serpentine red structures) are very close to each other without concern for isolation. Although the stacked vias are not continuous, they can be staggered so that the non-continuity is not an issue (see next page). This is for the case where there are two signals that do not share a common ground shield.

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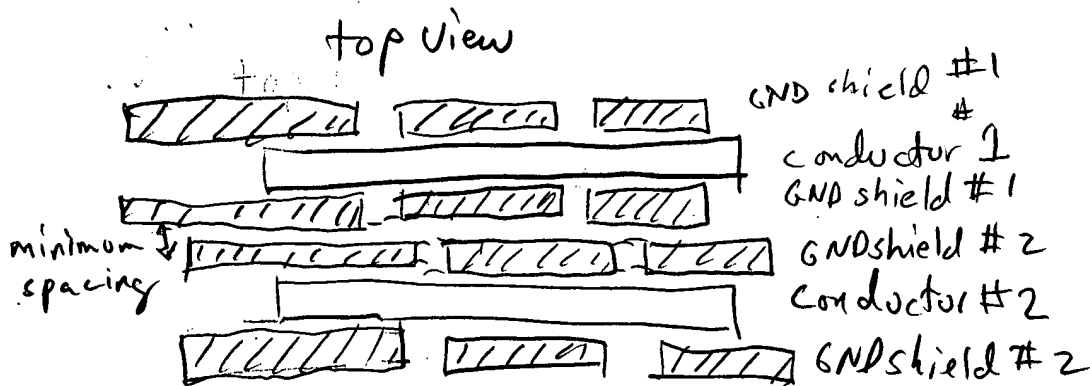
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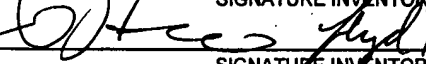
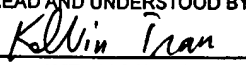
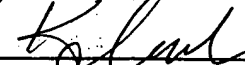


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By staggering the inter layer metal via stacks, there is never a spot in the router where there is direct coupling between conductors. By slightly increasing spacing between ground shields, isolation further improves. An example of a three layer coaxial line is shown on page 10. This structure allows signal routing above the shield for $N > 3$ metal layer process. Page 11 is an example of a fully enclosed SDR termination within a 5 layer coaxial line. The top and bottom layers are ground plane for full shielding, including any bondwire magnetic coupling. As part of the process of looking at prior art versus the new concept, an EXCEL spreadsheet was developed. This program calculated characteristic impedance as a function of geometries of metal and helped to model the coaxial line for HSPICE based simulations, to verify performance over BW.

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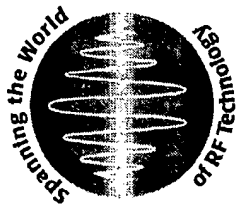
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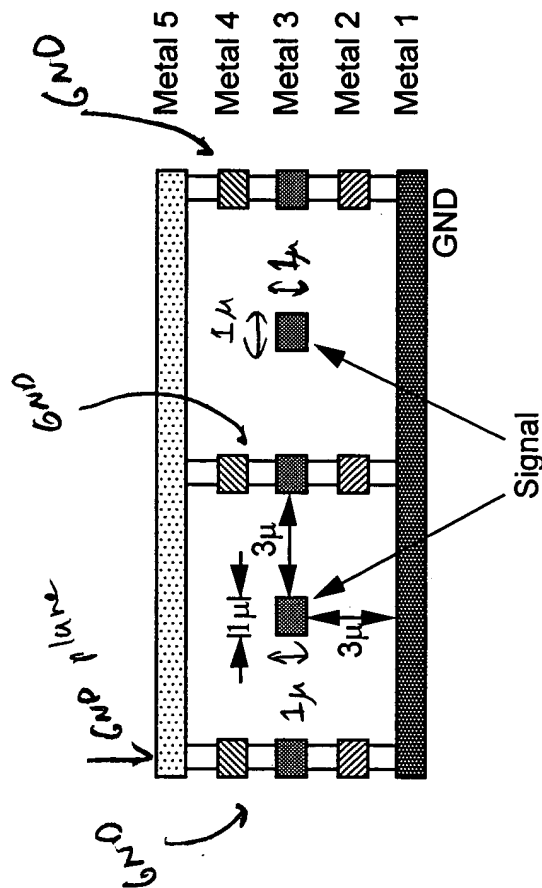
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On Chip Transmission Line

- On chip transmission line fabricated with 5 layer metal.
- Grounded shielding provides coax-like characteristic impedance line.
- Grounded shielding provides isolation otherwise unachievable on a small die.



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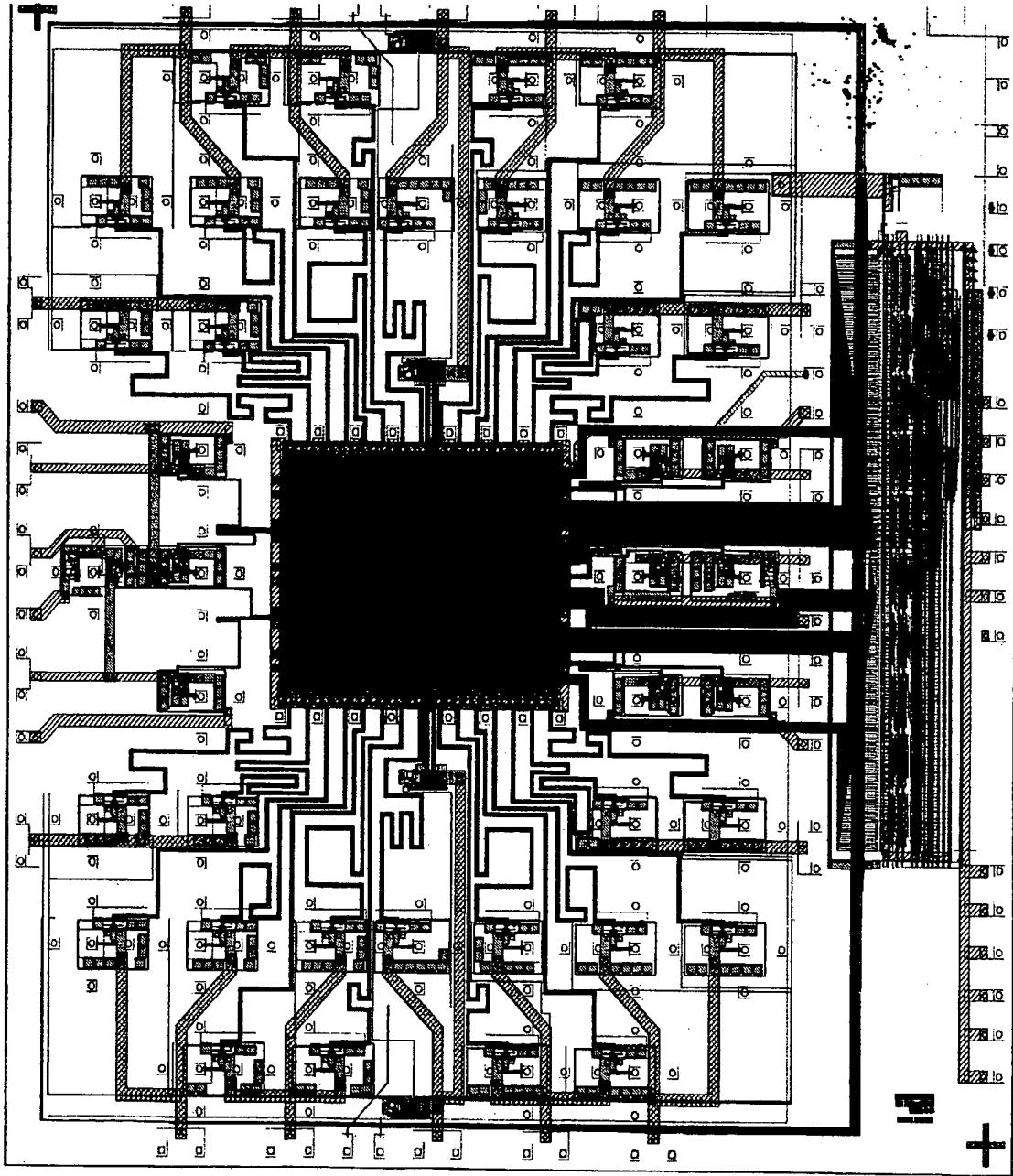
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Raytheon

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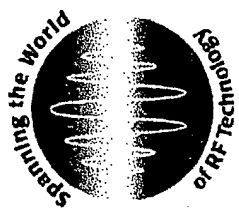
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IC Layout Plot



Raytheon

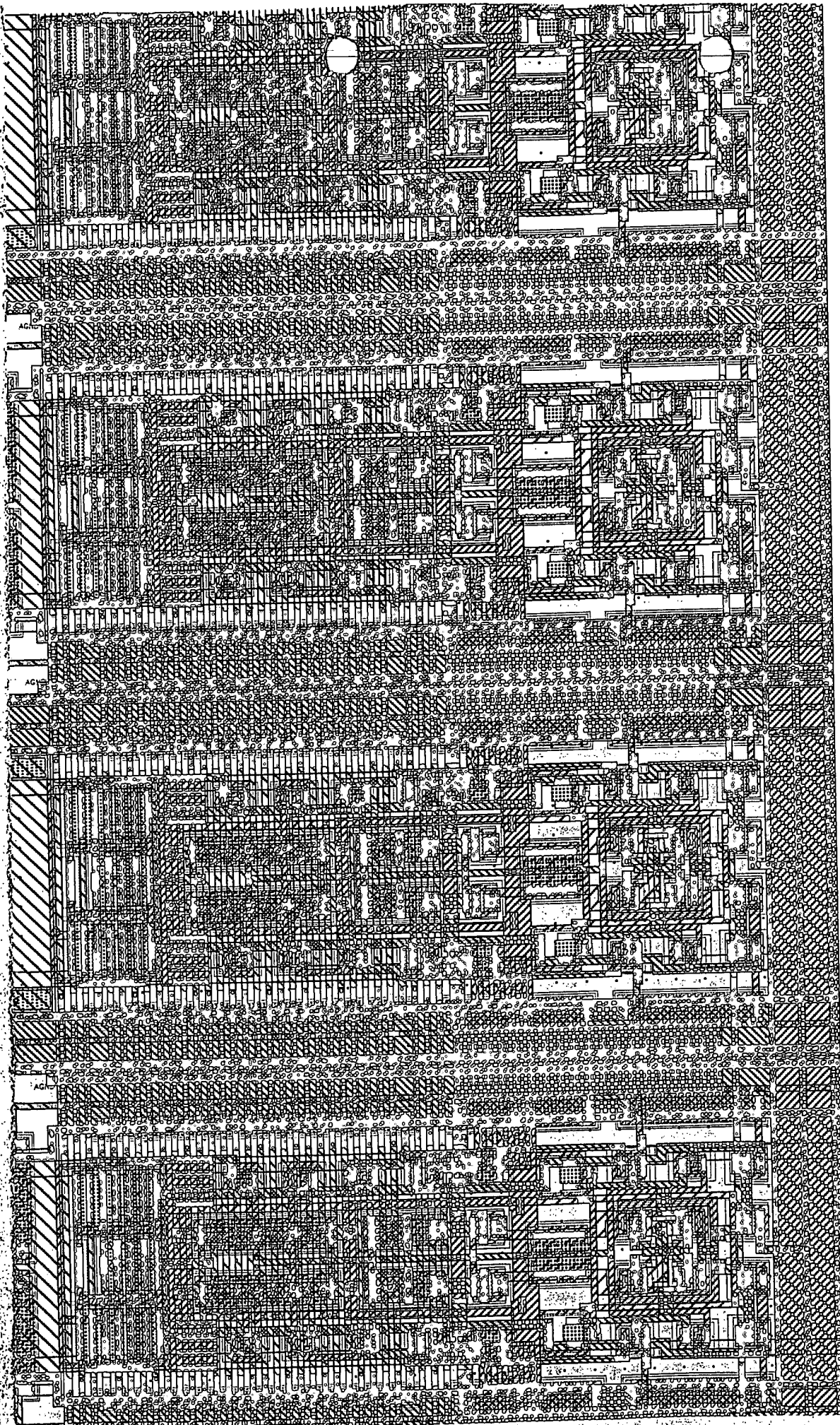
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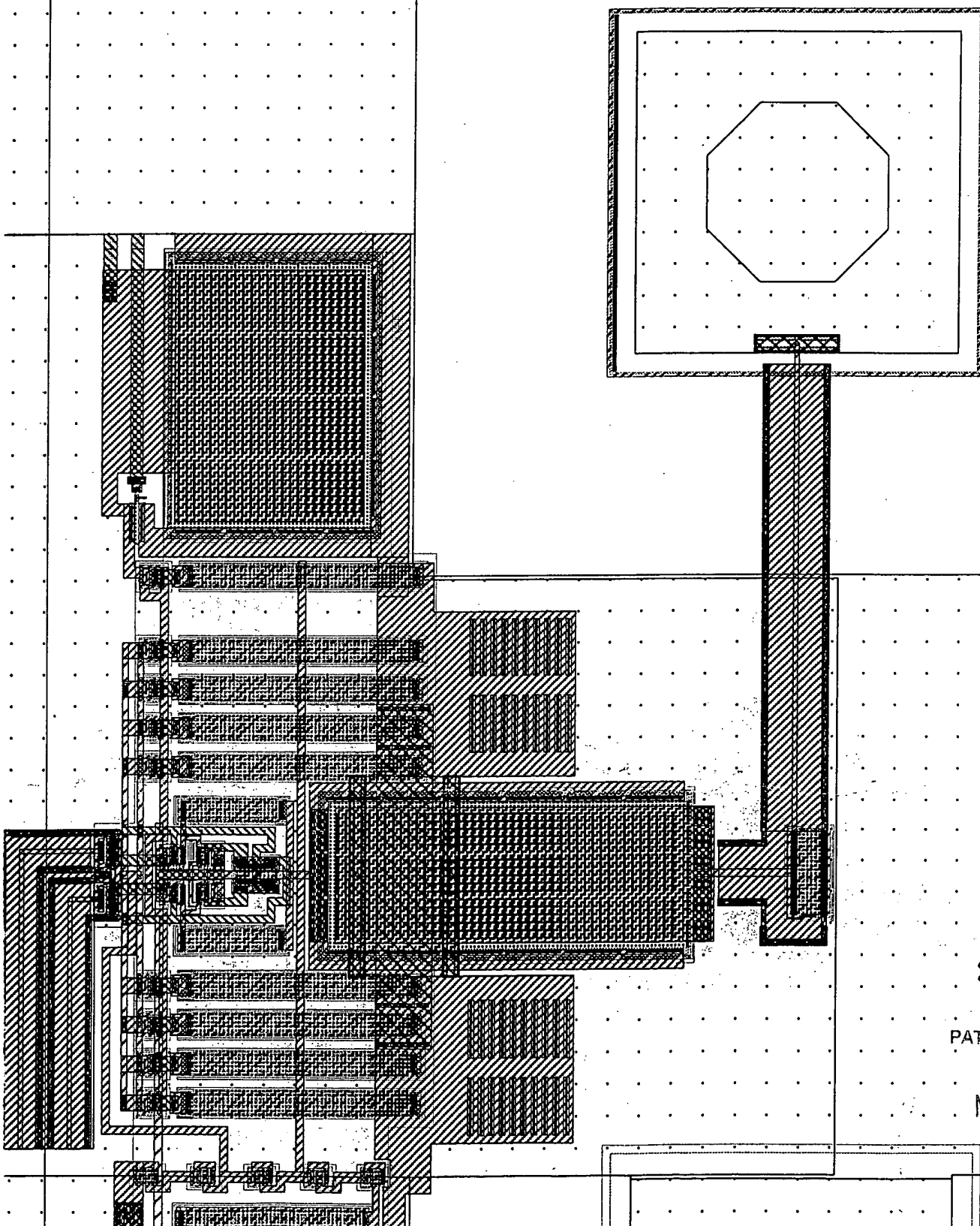


← 3 layer shield

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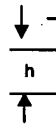


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| Row/Ht | From SiGe 47GHz Process Manual: | Nominal | +/- Tol | For M125: | Nominal | +/- Tol |
|------------------------------|---------------------------------|---------|---------|----------------------------|---------|---------|
| 41.89 | M5 | 2.07 | 0.20 | M5 | 2.07 | 0.20 |
| 24.29 | | 1.2 | 0.31 | | | |
| 17.20 | M4 | 0.85 | 0.08 | | | |
| 24.29 | | 1.2 | 0.31 | | 5.3 | 0.55 |
| 17.20 | M3 | 0.85 | 0.08 | | | |
| 24.29 | | 1.2 | 0.31 | | | |
| 17.20 | M2 | 0.85 | 0.08 | M2 | 0.85 | 0.08 |
| 24.29 | | 1.2 | 0.31 | | 1.2 | 0.31 |
| 12.75 | M1 | 0.63 | 0.06 | M1 | 0.63 | 0.06 |
| Nominals ADD, Tolerances RSS | | | | M1, M5 extend far beyond w | | |
| | | | | b = | 7.35 | 0.64 |



Program Inputs:

Desired Trace Width (uM)=

1.5

| I. Symmetric Stripline | | | | |
|---|-----------|-----------|-----------|--|
| | +ErrMax | Nom | -ErrMax | |
| er (SiGe dielectric) | 3.90 | 3.90 | 3.90 | |
| h (dielectric height) | 1.51 | 1.2 | 0.89 | |
| w (line width) | 1.5 | 1.5 | 1.5 | |
| t (trace thickness) | 0.77 | 0.85 | 0.93 | |
| MOTOROLA MECL SYSTEM DESIGN | | | | |
| w/(b-t) < 0.35 | 2.03 | 4.29 | -37.50 | |
| t/b < 0.25 | 0.51 | 0.71 | 1.04 | |
| Motorola Equation Valid? | Maybe Not | Maybe Not | Maybe Not | |
| Zo (Motorola MECL) | 39.39 | 33.51 | 26.82 | |
| S.B. COHN, J.F. WHITE | | | | |
| A=w/(2*b) < 0.35 Narrow, >= 0.35 Wide | 0.50 | 0.63 | 0.84 | |
| White, Cohn Narrow or Wide? | Wide | Wide | Wide | |
| Zo (White, Cohn) | 40.02 | 34.46 | 28.15 | |
| OTHER COMBINATIONS OF (h,w) (21,6), (24,7), (27,8), (31,9), (34,10) | | | | |

$$w/(b-t) = 0.23$$

$$t/b = 0.12$$

| II. Asymmetric Stripline | | | | |
|---|---------|--------|---------|--|
| From Howe: Stripline Ckt Design:p39 | | | | |
| s / 2 = trace center to (b/2) (equal) point | | | | |
| Asymmetry Calcs: | +ErrMax | Nom | -ErrMax | |
| w = | 1.50 | 1.50 | 1.50 | |
| wnew = | 1.67 | 1.63 | 1.59 | |
| t = | 0.77 | 0.85 | 0.93 | |
| b = | 7.99 | 7.35 | 6.71 | |
| s = | 4.10 | 4.10 | 4.10 | |
| b+s = | 12.09 | 11.45 | 10.81 | |
| b-s = | 3.89 | 3.25 | 2.81 | |
| 1- (t/(b-s)) = | 0.80 | 0.74 | 0.64 | |
| 1- (t/(b+s)) = | 0.94 | 0.93 | 0.91 | |
| [1- (t/(b-s))]^2 = | 0.64 | 0.55 | 0.42 | |
| [1- (t/(b+s))]^2 = | 0.88 | 0.86 | 0.84 | |
| (1 / Pi) = | 0.32 | 0.32 | 0.32 | |
| n = free space impedance = | 376.70 | 376.70 | 376.70 | |
| e = Er of SiGe = | 3.90 | 3.90 | 3.90 | |
| For w/(b-t)<0.35: | | | | |
| Wnew/b = (0.07(1-(t/b))+(w/b))/1.2 = | 0.21 | 0.22 | 0.24 | |
| cp1/e = 2wnew/(b-s-t) = | 1.07 | 1.36 | 1.88 | |
| cp2/e = 2wnew/(b+s-t) = | 0.30 | 0.31 | 0.32 | |
| cf1/e = (eq 2-11) = | 0.69 | 0.76 | 0.87 | |
| cf2/e = (eq 2-12) = | 0.54 | 0.55 | 0.56 | |
| (c/e) tot = cp1/e + cp2/e + 2cf1/e + 2cf2/e = | 3.82 | 4.28 | 5.06 | |
| Z0 = n * (1 / (c/e tot)) / sqrt(Er) = | 49.94 | 44.56 | 37.67 | |

Symmetric b = 2h + t

| | Default | Symmetric |
|-------------|---------|-----------|
| Asymmetric: | 7.35 | 3.25 |
| | 4.10 | 0 |

From SiGe Manual: rho(M2) = rho(M3)

| | Nom | tol |
|-----------------------------|-------|--------------|
| rho = | 0.045 | 0.01 ohms/sq |
| res per unit Length = rho/w | | |

Equations:

- $(Z_0)^2 = L / C$
- $(s^2) / Er = 1 / LC$; where s = speed of light, Er is epsilon rel

Therefore:

- $L = Z_0 * \text{sqrt}(Er) / s$
- $C = \text{sqrt}(Er) / (s * Z_0)$

| | +ErrMax | Nom | -ErrMax | |
|---------------|---------|--------|---------|---------|
| Asymmetric Z0 | 49.943 | 44.557 | 37.671 | |
| L = | 0.329 | 0.294 | 0.248 | pH/uM |
| C = | 0.132 | 0.148 | 0.175 | fF/uM |
| R = | 36.667 | 30.000 | 23.333 | mOhm/uM |

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